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SUPPORT OF HIGH VOLTAGE CONDUCTORS IN VACUUM

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FIG. 1

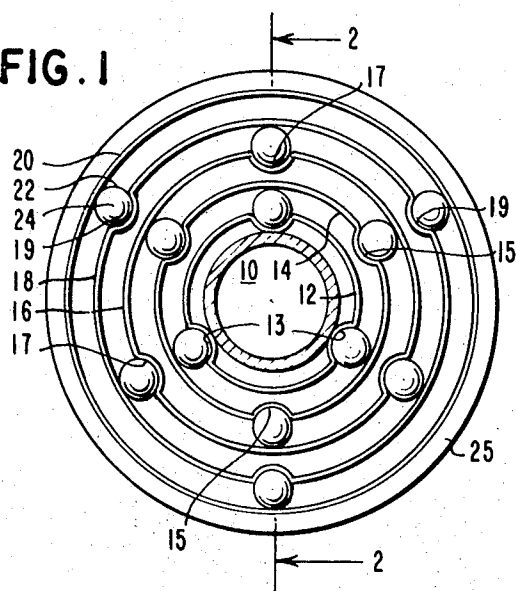


FIG. 2

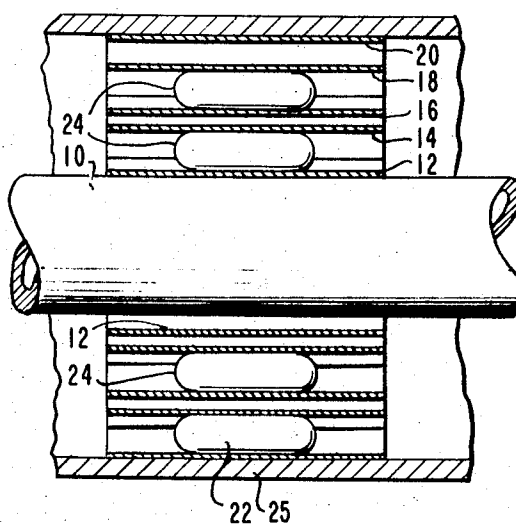
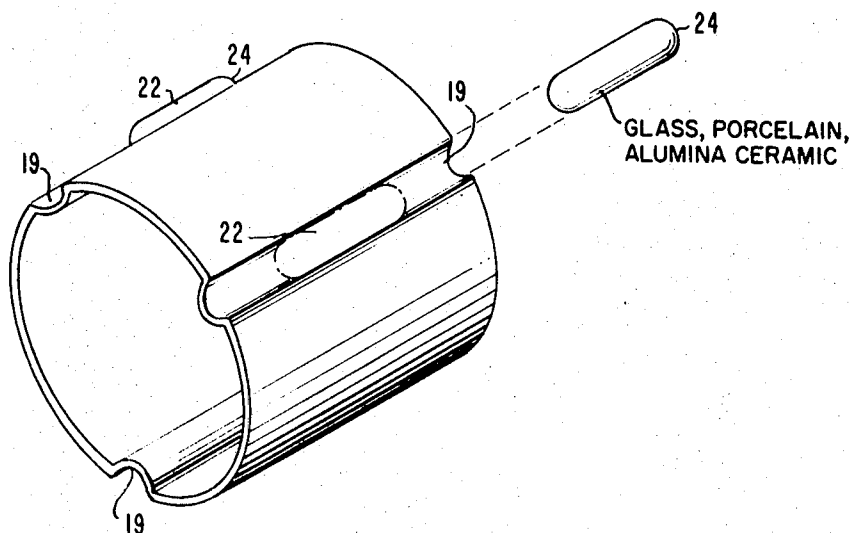


FIG. 3



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SUPPORT OF HIGH VOLTAGE CONDUCTORS IN VACUUM

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4 Claims

ABSTRACT OF THE DISCLOSURE

A supporting device for positioning a high voltage conductor within a vacuum environment, and particularly within tubular evacuated vessels. The supporting device includes one or more nested, coaxial tubes surrounding the conductor which are spaced between the conductor, each other, and outer structure, the tubes being spaced by dielectric spacers, which spacers are positioned between each pair of adjacent coaxial tubes to retain them spaced one relative to the other.

This invention relates to electric power transmission and distribution at high voltages, and in particular provides an insulated supporting device for a conductor positioned within a vacuum environment in a manner minimizing electrical breakdown at the location of the supporting device when a high potential is placed on the conductor.

Recently there has been interest in the transmission and distribution of electric power utilizing conductors insulated by a vacuum. Each power carrying conductor is usually enclosed within outer structure, such as an evacuated vessel, from which the conductor spaced by solid dielectric supports, such as spiders, positioned at intervals along the inner power carrying conductor. The outer structure is typically a grounded shield, another conductor or non-conductive structure. Such outer structure can form a vacuum-tight enclosure or it can itself be enclosed in a vacuum-tight tube or similar structure.

In such constructions the structure of the supporting devices is critical as electrical breakdown occurs readily at triple point junctions of vacuum, dielectric and conductor. Such breakdown may be caused by escape of electrons at a junction, or bombardment of a junction by charged particles. Any charged particles, i.e., electrons and ions, thus placed in an intense electrical field tend to accelerate rapidly in the evacuated space producing ion multiplication and ultimately electrical breakdown. The problem is aggravated by increasing distance because the possibility of ion multiplication is increased.

It is thus the primary object of this invention to provide a supporting device for the purpose described above in which the possibility of electrical breakdown adjacent the supporting device is minimized and yet which will provide for minimal spacing of the conductor from outer structure required to achieve proper insulation.

It is further an object to provide such a supporting device which is simple to fabricate and install on a mass production basis and which will provide good mechanical support for a high voltage conductor in a vacuum environment.

It is yet another object to provide a supporting device which eliminates the common practice of bonding glass to metal by firing in an oven which complicates manufacture and introduces the problem of matching thermal expansion coefficients.

It is still a further object to provide a supporting device which can be installed without the use of an adhesive or other organic materials, thus simplifying the installation procedure and eliminating possible contamination by

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volatiles occluded within the adhesive or other organic material.

In accordance with the present invention, these and other objects are obtained by providing a supporting device constructed of one or more tubular shields nested about the conductor which are spaced from each other and from the conductor and outer structure by relatively shorter dielectric spacers positioned such that vacuum-dielectric-conductor junctions are shielded by the shields to permit entrapment of charged particles on the shields before the particles can obtain velocities sufficient to produce ion multiplication.

To be more specific in the situation of one conductor, i.e., a high voltage transmission line, positioned within another conductor, i.e., a grounded shield, and the space therebetween evacuated to provide adequate insulation between the conductors for a high voltage applied across the conductors, it is contemplated in accordance with the present invention to provide one or more supporting devices for the inner conductor positioned at intervals along its length to hold the inner conductor uniformly spaced from the outer conductor, each such supporting device including at least one tube of conductive material nested between the inner conductor and the outer conductor and spaced from the conductors and other similar tubes by several dielectric blocks distributed about the tube on its outer side and by several dielectric blocks disposed about the inner side of the tube. The blocks in each case rest firmly against the tube, the outer set resting firmly also against the inner face of structure including the outer conductor and the inner set of blocks resting firmly against the outer face of structure including the inner conductor. All of the blocks are substantially shorter than the tube and are positioned relative to the tube intermediate the ends thereof to minimize exposure of the ends of the blocks in the electric fields that exist between the inner conductors when the high voltage is placed across the conductors.

It will be appreciated that preferably several such tubes are used concentrically positioned one about the other and spaced from each other and the inner and outer conductors in the same manner as described above with respect to one tube. While the spacing of the tubes from each other is uniform in the device described below, possibly a better spacer might be obtained if the inner gaps (spaces between tubes) were narrower than the outer gaps and so adjusted that each gap supports about the same voltage. Such a design might be described as "capacitance graded." Similarly the tube lengths need not be uniform, but might be disposed with shorter inner and outer tubes with the remaining tubes graded in length progressively from the inner and outer tubes to a longest tube in the center of the nest of tubes.

It will also be understood that, although the specific construction described above with respect to the drawings illustrates a situation employing cylindrical conductors and tubes, other shapes are feasible, for example, in a three-phase electric cable inner conductors can be of sectoral shape as are the outer conductors. Thus, the tubes provided in accordance with the invention will also have an approximate sectoral shape. Other shapes can also be employed, such as elliptical and the like, as dictated by the intended usage of the cable.

In the drawings:

FIG. 1 is a cross-sectional view of a pair of conductors and of a supporting device in accordance with the invention holding one conductor spaced within the other;

FIG. 2 is a longitudinal view of the conductors and supporting device taken along lines 2—2 of FIG. 1, and

FIG. 3 is a perspective, exploded view of a portion of the supporting device.

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In FIG. 1, reference numeral 10 refers to a conductor which can be copper or aluminum or the like, preferably anodized aluminum, and which has a centrally located conduit for passage of a cryogenic fluid, such as liquid nitrogen under a pressure of 10 to 20 atmospheres and at a temperature of 60° to 100° K. While the fluid is used in the illustrated case to remove I²R losses, if liquid helium is employed, conductor 10 can be made of lead or the like in order to take advantage of its super-conducting properties at the temperature of liquid helium.

Coaxial with and surrounding conductor 10 are five concentrically oriented cylindrical metal tubes designated by reference numerals 12, 14, 16, 18 and 20. The tubes can be of bare or plated metal or of metal covered with a thin layer of dielectric material. Stainless steel, titanium, nickel plated copper, anodized aluminum and silicon monoxide covered tungsten are among the suitable materials. Anodized aluminum is preferred, however. Each of the four interior tubes, i.e., tubes 12, 14, 16, and 18, has three inwardly rounded, longitudinal depressions. These are designated by reference numerals 13, 15, 17, and 19, respectively. Depressions 15 are arcuately displaced from depressions 13 and likewise, depressions 17 are arcuately displaced from depressions 15. The depressions are seen to best advantage in FIG. 3, and they run the length of the cylindrical tube.

In the depressions are solid, short spacers of dielectric material, for example, glass, Pyrex glass, porcelain, glazed porcelain, Micalex, alumina ceramic, or the like, which are in the form of rods lying lengthwise in depressions 13, 15, 17 and 19 to maintain the concentric relationship of the tubes and which have a high degree of mechanical strength. These short glass rods are designated by reference numeral 22. They are seen to best advantage in FIGS. 2 and 3. It will be noted that the ends are rounded as shown at reference numeral 24 and that rods 22 are significantly shorter than tubes 12, 14, 16, 18 and 20. There is nothing critical about the number and shape of the dielectric spacers utilized. It is essential only that enough spacers be employed to provide firm support of each tube 12, 14, 16, 18 and 20; that the spacers be shorter than the tubes and hence positioned within the tubes; and that due consideration be given to the elimination of sharp edges and points.

To install the assembly of tubes 12, 14, 16, 18 and 20 about conductor 10 and within an outer conductor 25 which functions as a grounded shield, for example, where relatively short lengths of conductors are employed, a first set of tubes and glass rods are assembled, as shown in FIG. 1, with the opposite ends of tubes 12, 14, 16, 18 and 20 abutting common planes and with rods 22 centered between such planes, their ends 24 thus being spaced inwardly of the ends of the tubes. The assembly is then positioned over the end of a conductor 10, and is slipped along with conductor 10 within an end of conductor 25 which desirably provides a tight sliding fit for outer tube 20.

Conductor 10 is positioned to lie totally within outer conductor 25 except that its ends may project as required for suitable termination. At the same time the assembled set of tubes 12, 14, 16, 18 and 20, together with rods 22 in position, as shown in FIGS. 1 and 2, is positioned adjacent an end of the pair of conductors 10 and 25, for example by utilizing an annular plunger designed to fit between conductors 10 and 25. A second set, and a third set or more, as may be desired, of tubes 12, 14, 16, 18 and 20 are then assembled one at a time

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with spacer rods 22 and slipped over an end of conductor 10 and are positioned down between conductor 10 and conductor 25 to provide as many supporting points between conductors 10 and 25 as are required.

Suitable terminations are then made at the ends of the conductors. The space between them is then evacuated and the conductors are prepared for application of high voltage. The supports provide for entrapment of electrons escaping at vacuum-dielectric-conductor junctions since such junctions all lie within the shielding effect provided by tubes 12, 14, 16 and 18, and electrons can accelerate only short distances before striking a conductor or shield tube surface where they remain trapped. At the same time good mechanical rigidity is provided.

I claim:

1. In a vacuum insulated high voltage cable having an inner conductor and outer structure including an evacuated enclosure in which said inner conductor is positioned: the improvement which includes a supporting device holding said inner conductor spaced within said outer structure, which supporting device includes a tube of conductor material nested between said conductor and said outer structure and spaced therefrom, a plurality of dielectric spacers positioned about and in contact with the outer surface of said tube and positioned within said outer structure in contact with an inner surface thereof, and a plurality of dielectric spacers positioned about and in contact with the inner surface of said tube and with structure including said inner conductor, said spacers being shorter than said tube and the ends of said spacers being positioned inwardly of the ends of said tube.

2. A supporting device according to claim 1 in which said tube includes means defining a plurality of depressions disposed at intervals about said tube, said spacers in contact with the outer surface of said tube being disposed each in a said depression.

3. The supporting device of claim 1 wherein said spacers are cylinders of ceramic material having rounded edges.

4. A supporting device for holding an inner conductor spaced within outer tubular structure which includes a plurality of tubes of differing cross-sectional dimension nested together for positioning said conductor and said outer structure, and a plurality of dielectric spacers positioned between the adjacent surfaces of each adjacent pair of tubes and in contact with said adjacent surfaces to retain each adjacent pair of tubes spaced from each other, each said dielectric spacer being shorter than the tubes which it contacts and the ends of said spacer being positioned inwardly of the ends of the tubes which it contacts.

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U.S. Cl. X.R.

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